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TITLE

THE EFFECTS OF CONTROL MEASURES ON THE MOUNTAIN PINE BEETLE (DENDROCTONUS MONTICOLAE HOPKINS) IN LODGE POLE PINE TETON NATIONAL FOREST, JACKSON, WYOMING

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Forest Insect Laboratory
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January 4, 1949

To: F. C. Craighead, In Charge, Forest Insect Investigations

From: James C. Evenden, Box 630, Coeur d'Alene, Idaho

Subject: Effects of Control Measures on the Mountain Pine Beetle in Lodgepole Pine -----, by James L. Bean

The method of treatment as adopted in 1948 for the Targhee-Teton mountain pine beetle infestation in lodgepole pine, was to treat standing infested trees. Portable spray equipment had been developed that would throw a fine stream of fuel oil for immediate burning, or of penetrating spray to a height of 30 - 35 feet. It was realized that this height would not reach to the top of the infested bole on all trees. Past records of infested heights on lodgepole pine trees in this region, showed that this treatment would destroy approximately 95% of the total beetle population. It was considered that the benefits of this method of treatment more than offset this loss. In fact this project would not have been feasible had it been necessary to fell the infested trees for treatment.

Artificial control measures can seldom take into consideration the natural factors of control which contribute so materially to maintaining destructive insect populations to a below epidemic level. It was thought that if there was a heavy mountain pine beetle parasite and predator population in the upper portion of the infested bole, that perhaps we should reduce to a height of treatment from our maximum of 30 - 35 feet. This and other questions were to be answered in connection with this project.

Mr. James L. Bean, Forest Insect Laboratory, New Haven, Connecticut, was detailed to the Targhee-Teton project to undertake studies which would answer these questions. We appreciated Mr. Beans assistance. Although he did not find what we had hoped he might, he performed an excellent bit of work, during the rather short period of his assignment.

E.F.C.Craighead-1/4/49

A copy of Mr. Bean's report of this project is enclosed for your information and files.

Your comments will be appreciated.

cc: Keen
Furniss
Wygant
Bean
Eastern Labs.

The Effects of Control Measures on the Mountain Pine Beetle (*Dendroctonus monticolae* Hopkins) in Lodge Pole Pine Teton National Forest, Jackson, Wyoming

By
James L. Bean, Entomologist

In the application of artificial control measures to suppress destructive insect outbreaks the question naturally arises as to their effect on natural control factors. Is it possible to apply widespread and urgent control measures and still retain the effectiveness of existing natural controls, i. e., parasites and predators? It was with this in mind that the first part of this study was undertaken. The second part was to determine the effectiveness of the control measures used on the Targhee-Teton Bark Beetle Control Project in 1948. These measures consisted in treating standing infested trees with a spray that penetrates the bark and killed the broods beneath or with fual oil which was subsequently ignited and which generated sufficient heat to kill the broods beneath. It was realized that with the equipment available it would be impossible to reach the full height of infestation on all trees. This phase of the study was directed toward determining the importance of leaving this portion of the infested bole untreated.

The data obtained will be discussed under two main headings, namely; A. The Distribution of the Mountain Pine Beetle and its Parasites within the Infested Bole of Lodgepole Pine Tree, and, B. The Effectiveness of Present Control Measures on the Mountain Pine Beetle. All data were obtained in the vicinity of Mosquito Creek, Teton National Forest, Jackson, Wyoming. Five trees were examined at the Teton National Park the last of May for comparison with data obtained at Mosquito Creek.

A. The Distribution of the Mountain Pine Beetle and Its Parasites within the Infested Bole of Lodgepole Pine Trees

This phase of the study will be divided into five separate sub-headings, as follows:

1. Technique of obtaining data
2. An analysis of the parasite data
3. An analysis of the mountain pine beetle brood data
4. The Woodpecker - an important predator
5. A brief summary of this phase of the problem

1. Technique of obtaining data

The time allotted to this study made it necessary to limit the amount of material collected for examination. A total of 29 infested trees were felled and examined; 24 of them were from the Teton National Forest and 5 from the Grand Teton National Park. Infested trees were felled and the bole examined to determine the length of the infested area. That part of the bole infested, including the stump, was measured and divided in to thirds. The midpoint of each third was then determined and a section one foot long removed at this point. (see photo 1). Each section was marked as to tree number and distance from ground. In addition to the above information the Dbh, total height of tree, and height to which woodpecker work was visible from the ground were recorded. (See attached form).

Each one foot section was then taken back to camp for detailed examination. A measured amount of infested bark was carefully removed and the following data were recorded; The number of living new adult beetles, pupae, larvae--egg to one-half grown (listed as 0-1/2) and one-half to full grown (as 1/2 - 1), number of beetle attacks that originated on the section, number and species of known parasites and predators, percent of infested bark removed by

woodpeckers, average bark thickness and square feet of bark removed for examination, and the mid-diameter of each section. (A complete summary of all data is given in Table I).

In addition to the above data general observations were made during other phases of this study and are incorporated in the following discussion.

2. An analysis of the parasite data.

In past studies of the habits of this beetle in western white pine, investigators found that the upper portion of the infested bole supported a major percent of the parasite population. It was hoped that this condition would prevail in lodgepole pine, which would minimize the danger of leaving untreated brood in the upper portion of the bole.

On the basis of the data secured in this study 69 percent of all parasites were in the basal third of the infested bole, 27 percent in the middle third, and 4 percent in the top third. (See Table II). These percentages are based upon data secured at the Teton National Forest. The number of trees examined at the Park were too few for proper analysis. Therefore, it must be assumed that in trees properly treated a big percentage of the parasite population will be destroyed. This is especially true on trees that receive the oiling and burning treatment.

Table I

Teton National Forest — Individual Tree Summary

Tree No.	DBH	Length	Area of Infestation: Approx. Sq.ft. Bark	Area of Infestation: Sq.ft. of Bark Exam.	Total Brood: Adults	Total Brood: Pupae	Total Brood: Larvae 1 -1/2	Total Brood: Larvae 1/2-0	No. Attacks	Parasites: Medeterus aldrichi	Parasites: Coeloides Sp.	Parasites: Cleride
1	9.0	13.0'	30	7.4		1	394	303	68	12		
2	12.4	18.5'	57	10.9	1		105	675	17	4		
3	12.0	10.0'	31	9.0			181	126	72	7		
4	15.0	16.0'	63	11.5			23	140	7			
5	20.0	44.0'	208	7.0		1	339	318	57	79	6	
6	11.0	35.0'	101	8.1	1	4	80	208	18	3	5	
7	12.5	12.0'	35	3.0			15	543	10	7		
8	11.0	24.0'	57	4.5			322	885	46	2		
9	10.1	10.0'	26	3.4			166	136	35	3		
10	8.1	11.0'	20	4.6			40	159	11			
11	13.0	18.0'	57	3.2			42	197	9			
12	14.3	23.0'	84	5.0			317	614	53	1		
13	13.9	32.0'	109	3.2			4	204	6	3		
14	13.5	18.0'	59	4.5			-	175	52			
15	17.3	20.0'	79	7.2			124	67	46	8	7	1
16	14.8	30.0'	102	3.4			19	345	17	4		1
17	11.9	17.0'	49	3.4			52	193	12	1		2
18	18.3	31.0'	130	6.0			724	362	42	1		
19	13.2	24.0'	75	4.1			35	110	9	11		
20	12.7	24.0'	69	5.0			440	308	28	2		
21	13.8	16.0'	55	4.5			50	360	31	2		
22	15.2	16.0'	59	4.5			71	289	21	6		
23	7.0	21.0'	33	4.3			89	175	20			
24	11.9	26.0'	68	4.4			343	169	14	5		

Teton National Park

Tree No.	DBH	Length	Area of Infestation: Approx. Sq.ft. Bark	Area of Infestation: Sq.ft. of Bark Exam.	Total Brood: Adults	Total Brood: Pupae	Total Brood: Larvae 1 -1/2	Total Brood: Larvae 1/2-0	No. Attacks	Parasites: Medeterus aldrichi	Parasites: Coeloides Sp.	Parasites: Cleride
1	11.2	19.0'	48	3.3			200	9	23			2
2	14.2	20.0'	64	7.0		6	648	160	59	4		2
3	12.0	9.0'	30	2.8			372	38	24			
4	12.8	11.0'	36	2.7			166	94	29			1
5	14.2	41.0'	153	7.0	8	43	52	22	34			1

TABLE II

Distribution of Parasites by Sections

Section of Infestation	Sq. ft. of bark examined	*Medeterus aldrichi*	*Coeloides* sp.	% of total parasites per section
Basal third	45.2	125	1	69
Middle third	47.0	32	17	27
Top third	39.9	4	0	4
Total	132.1	161 (90%)	18 (10%)	

A single tree, sprayed with the ortho-oil mixture in October, 1947, was examined May 20th, 1948 to see what effects this treatment had on the parasite population. These data are given in Table III. Although these data are only from one tree they show some indication of a possible parasite survival following fall treatment. The majority of the parasite larvae noted, and especially those in the top part of the bole, were in their early stages of development. Three reasons may be given to explain this survival. 1. Beetle broods are protected somewhat by the thick bark at the base of the tree and around knots; 2. Green bark also seems to act as a deterrent to the penetration of the ortho-oil; and 3. Low, thick crowns often prevent the proper application of the spray to the upper portion of the infested bole. A subsequent examination of this and other similarly treated trees made in late June show no beetle brood survival.

Table III

The Distribution of Medeterus aldrichi in a tree treated with "Ortho" October, 1947.

Distance from ground in ft.	Dead Parasites per sq. ft.	Living Parasites per sq. ft.	Living Beetle Larvae per sq.ft.
0 - 1	4	6	12
3	8	12	9
6	4	12	3
12	7	16	7
30	3	14	22
35	3	8	30 +

Although several species of parasites are known to attack the mountain pine beetle only two of them were encountered in this study. They were Medeterus aldrichi Wheeler, (Dolichopodidae, Diptera), and Coeloides sp. (Braconidae, Hymenoptera). The dipterous parasite was by far the most numerous, being 90 percent of the total number counted (See Tables I and II). All larval instars of this parasite were recorded during the period of examination. The distribution of these two parasites by thirds of the infested bole is given in Tables II and IV. An interesting thing noted is the small number of Coeloides sp. recorded, and that nearly all of them are in the middle third. On June 7 numerous adult Coeloides were found ovipositing on infested trees.

Table IV

Relationship of Parasites to Brood

Section of Infestation	Parasites per sq. ft.	Pine Beetle Brood per sq. ft.
Basal third	2.6	90.7
Middle third	1.0	84.6
Top third	0.1	64.4

Of the known insect predators of this beetle only a few (4) larvae of the red-abdomen clerid were recognized. It was not until May 25 that an adult of this clerid was captured at Mosquito Creek. Numerous adults and several nearly matured larvae were found on infested trees examined at Teton National Park on May 31. Indications are that this predator will be more abundant during June and July.

The appearance of adult Cocloides and the predatory clerid at the beginning of June may be of significance in the final analysis of natural control factors following artificial control. A study of parasitism following the application of an ortho-oil treatment may give some interesting data on final beetle emergence after such control measures are used.

3. An analysis of the mountain pine beetle brood data.

If one may make use of the data secured at the Teton National Park approximately 3 percent of the brood had reached the pupal stage, and 1/2 of 1 percent the adult stage during the period from May 4 to May 31. General observations at Mosquito Creek seem to bear this out. Variations, of course, will occur in individual trees depending on the amount of sunlight received by the infested bole. The more the exposure the higher the percentage, and vice versa.

The average height to which the infestation occured on the bole was one of the important questions answered by this study. All infested trees were treated standing, and the height to which treatment could be applied was approximately 35 feet. The average infested length in this area was 21.2 feet with a maximum of 44 feet. Only an occasional tree would be found in which the infestation extended beyond the 35 foot point. Under control measures factors influencing proper treatment to the maximum height will be discussed.

In an attempt to analyze the brood data no correlation could be found between brood per square foot and tree diameter, height, or bark thickness. This may be due to the small number of trees examined. There was, however, a marked relationship between brood per square foot and length of infestation, and a slight relationship in the development of the larvae to bark thickness. The relationship between brood per square foot and the three divisions of the infested bole is shown in Tables IV and V. In either case the number of brood and number of attacks are greater in the basal third than in either of the other two; the middle and top third following in that order. This may indicate that the basal portion of the bole is more attractive to the attacking female than the other portions.

Table V.

The Average Distribution of Mountain Pine Beetle Brood

Section of Infestation	Total Brood per Square Foot				Number Attacks
	New Adults	Pupae	1 - 1/2	1/2 - 0	
Basal third	.04		62.1	120.0	6.6
Middle "	-	.2	60.8	104.7	5.0
Top "	.04	-	42.5	69.4	4.2

In Table V it will be noted that the percent of 1-1/2 larvae is closer to that for 1/2-0 in the top third than in the other portions of the bole. These figures are based upon remaining larvae and no account is made of those removed by woodpeckers. Furthermore, in the examination of the sections, areas heavily woodpecked were omitted. In the discussion under the subheading on woodpecker work it will be seen that this predator concentrates mainly on the basal and middle third.

Although bark thickness is not closely correlated with the degree of infestation it is of some importance in the rapidity of larval development. The thicker the bark the less fluctuation there is in temperature and humidity, resulting in a longer period of development in the fall. This can be readily seen in the basal portion of the stump, around knots, and in crevices. Under the discussion of control measures it will be shown that thick bark also plays an important part in decreasing the effectiveness of control.

Closely associated with the beetle attack is a blue stain of the sapwood. (See Photo #2). From the area stained it is possible to determine the amount of the bole circumference infested and the degree of the infestation.

Hedard and Terrell (1939), in their study of the mountain pine beetle in western white pine, developed a practical formula whereby it was possible to determine the tendency of an outbreak of this beetle to increase or decrease the following year provided conditions remain the same. In the application of their formula to this study the following answer was obtained. For every tree that is infested this year there will be 2.2 trees infested next year. This figure, of course, does not take into account the present control program.

4. <u>The woodpecker - an important predator.</u>

An important predator of the mountain pine beetle in this area is the woodpecker. Most trees that contain mountain pine beetle broods will have some woodpecker work. In Photo #3 the pine to the left has been nearly stripped of its bark from about one foot above ground level to the first large branch on the right of the bole. Pines to the right are not infested.

No attempt was made during this study to determine the actual number of beetle larvae destroyed by these birds, but from the intensiveness of their work the number must be enormous. On heavily infested trees over 90 percent of the bark may be removed from a point about one foot above ground level to a point three or four feet below the total height of beetle attack. Only an occasional small patch of bark will be left and these are usually around large knots or in crevices.

The effectiveness of this predator is not only measured by the larvae removed, but by the resulting effect of its work on those remaining. The numerous holes made by this bird and the removal of large patches of bark lowers the humidity and increases the temperature under the bark that remains to such an extent that the brood beneath this bark, especially the small larvae, is greatly arrested in its growth and many of the larvae die. Mortality will increase as hot weather approaches, as was evident in the sections from the Teton National Park. Furthermore in her ever amazing fashion, nature provided this bird with the ability to locate the larger, heavier broods hidden beneath the bark. Little time is wasted looking for light broods or small larvae. As a result a larger percent of the brood is destroyed than the percent of bark removed indicates.

From the examination of 50 trees, 80 percent showed noticeable woodpecker work. The average amount of infested bark removed from these trees was 36 percent of the infested length. On trees with an infested length of less than 10 feet, or those in which the brood had been partly pitched out, woodpecker work was almost completely absent. During the 1947 survey of this area very little woodpecker work was noticed. Practically all the work by this bird was carried out during the winter of 1947-1948.

In the process of examining trees for this study it soon became evident that there was a close correlation between the upper limits of infestation and height of woodpecker work visible from the ground. With but few exceptions an observer could determine, on a medium or heavily infested tree, the approximate height of the infestation by the height of the woodpecker work. Generally the visible woodpecker work extended up to within three to five feet of the limits of infestation.

It might also be added that woodpecker work is a marked visual aid to the spotters in finding "bug" trees.

5. A brief summary of this phase of the problem.

Only two species of parasites (Medeterus aldrichi Wheeler and Cooloides sp.) were recorded during this study. Their distribution in relation to the infested length was 69 percent in the basal third, 27 percent in the middle third, and 4 percent in the top third. The parasite M. aldrichi was by far the most numerous, 90 percent of the total. While this parasite was most numerous in the basal third nearly 100 percent of the Cooloides sp. was in the middle third. The red-abdomen clerid was the only insect predator recorded. Very few of these were found during the first part of the examination, but they became more numerous the last part of May.

On this project the woodpecker was apparently one of the most important predators of this beetle. Approximately 80 percent of all infested trees were attacked by this bird, with approximately 36 percent of the infested bark removed.

B. The Effectiveness of Present Control Measures on the Mountain Pine Beetle.

The second phase of this study is devoted to a brief analysis on the effectiveness of the two types of control measures used on this project. They are 1. Oiling and burning, and 2. Spraying with an ortho-oil mixture. Each of these two types will be discussed under their respective headings. The data obtained from this study is merely a rough estimate of the percentage of mortality and expected mortality. No attempt was made to make a thorough tree analysis of each control measure.

This part of the problem will be divided into the following three sub-headings: 1. Technique of obtaining data. 2. Oiling and burning, and 3. Ortho-oil mixture.

1. Technique of obtaining data.

Most of the information obtained on this study has already been established by other investigators, but it was considered advisable to make a rough and rapid check on the present control project to determine if the same effects occurred. In order to do this the writer, with the aid of two other men, felled and examined 34 trees which had been burned, and 114 trees treated with the ortho-oil mixture. In addition 90 standing trees treated with "ortho" were examined from the ground up to approximately five feet on the bole.

In this examination the tree was felled and patches of bark removed from the stump and along the bole up to the end of the infestation. (See Photo 4). Following the removal of this bark a rough estimate was made of the percent of mortality. On "ortho" treated trees a rough percentage estimate was also made of the expected mortality. The expected mortality was based upon the color and sluggishness of the larva, also on its position in the tunnel. Generally the larva, when affected by the "ortho" mixture, reversed its position in the tunnel. (See Photo 5). Trees were selected in which the time lapse between treatment and examination varied from 24 hours to 21 days. The basal examination was adopted in the final phase of this study to speed up the examination, as it was noted that this gave as good a picture of the mortality as felling the tree and examining the entire bole.

2. Oiling and burning.

This method of treating infested trees was used during the early part of the season when there was no danger of developing forest fires, but was abandoned when the use of fire became hazardous. In the application of this treatment approximately 2 to 3 gallons of fuel oil No. 2 were sprayed over the bole of the infested tree to the maximum height possible with the equipment in use. This oil was then ignited, by tossing a lighted match to the base of the tree, and allowed to burn off. The heat of the burning oil ignites the outer bark flakes and resinous pitch tubes, and enough heat is generated to penetrate the bark and destroy the insect broods beneath. (See Photo 6). On some trees the basal 12 inches of the stump was hacked with a hand axe prior to burning; the reason being that the thick bark at the base did not allow the penetration of sufficient heat to kill the brood beneath. On a properly burned tree the flakes of bark show gray ash.

During the examination of trees treated by this method it soon became evident that several factors were quite important in obtaining proper control. One of these has been noted above, that is the thickness of the bark at the base of the tree. The hacking of the bark at the base, and reburning when necessary, greatly reduced the number of surviving larvae. Roughly a maximum of 5 percent of the larvae in this portion of the tree may survive this treatment. Usually the surviving larvae are near the root collar or in crevices formed by the larger roots.

The next important factor is the "crowning-out" of the fire. When sufficient oil has been applied to the infested bole sufficient heat is often developed to force the fire up through the crown. Trees treated in this manner usually show complete control. No living larvae were found in the tops of trees in which the fire had "crowned-out." (See Photo 7). Photo 8 illustrates a tree in which the fire did not "crown-out." Note the grayishness of the bark in the vicinity of stump as compared with tree in background. Partial control stopped at the peeled area just to the left of the stump. Living brood extends to the axe - far right. The distance from stump to base of tree (not shown) is approximately 20 feet.

The third important factor is to develop sufficient heat to effectively char the bark which in most instances destroys the brood beneath. Several trees were examined in which this condition did not occur. These trees were quite evident from the dark grayishness of the bark. The mortality on these trees ran quite low, approximately 35-40 percent of entire brood. This condition could be caused by first, the use of insufficient oil, or too long a delay between the application of oil and the time it is ignited. During such a delay there may be sufficient evaporation of the oil, to render the treatment ineffective.

Briefly, this method of treating infested trees will give almost complete control if properly performed, but the danger of using fire limits its use to only a short period of the season.

3. Ortho-Oil Mixture

This method of control involves the spraying of infested trees with a mixture of orthodichlorobenzene and fuel oil No. 2. The ortho-dichlorobenzene is the toxic agent while the oil is the carrier or penetrating agent. The "ortho" is mixed with the oil at the rate of 1 gallon to 5 gallons of oil. Approximately the same amount of this mixture is used per tree as in burning, i.e. 2-3 gallons. At the start of this project a 1-6 mixture of these chemicals was used. This was later changed to a 1-5 ratio in order to obtain better penetration through thick bark.

The reaction of this spray is often slow, especially in cold weather. Trees sprayed in the fall of 1947 did not show complete mortality until late June.

The system used in examining trees treated by this method was the same as that used in the burning treatment.

This method of control can be briefly summarized as follows: Trees treated by both mixtures were examined one week after the application of the spray showed a 50 percent mortality for the 1-6 mixture and 60 percent for the 1-5. Past use of this spray has shown that this percent of mortality will increase to nearly 100 percent as the weather becomes warmer. The heat of the sun seems to hasten the bark penetration of the "ortho" which obviously increases its toxicity. Wherever heavy woodpecker work occurred the percent of mortality was much greater, and in areas where the bark was thick, such as at the base of the tree, it was much less--usually around 10 percent. Another noticeable factor in the rate of mortality is green bark. Larvae found working in green bark adjacent to that killed by the insect and in the upper limits of the infested bole, showed a much lower percent of mortality than those under dead bark. The higher moisture content and the presence of pitch may be the influencing factor here.

As a rough check on the rate of mortality, for the 1-5 mixture, in relation to the lapse of time five groups of trees were examined 1, 2, 3, 16, and 21 days after treatment. The mortality was roughly 5, 15, 35, 70, and 80 percent respectively.

The toxicity of the ortho-oil mixture has been proven on several occasions by previous investigations, but it might not be amiss to add one more proof. During late October and early November 1947, a group of trees in this same general area were felled and treated with "ortho" (1-6 mixture). Shortly after treatment a heavy snowfall covered the logs and prevented the continuation of this control project. On May 5, 1948, these logs were examined and it was estimated that approximately 75 percent of the larvae were living. On May 26th these logs were again examined and nearly 100 percent mortality had occurred. Without doubt, a small percent of this mortality was caused by solar heat, but this same heat also increased the effects of the "ortho".

The effectiveness of these two methods of control may be briefly summarized as follows: The oil-burning treatment was satisfactory when properly applied. Larvae which escaped the heat were able to complete their development. The ortho-oil treatment is better suited for this type of control. It is equally as effective when properly applied, eliminates the danger of fire, and the increased expense is of little importance. It is slow of action, but increases as the weather becomes warmer.

Photo 1. Infested log showing where the one foot long sections have been removed. Axe marks end of infestation, and note book indicates end of woodpecker work.

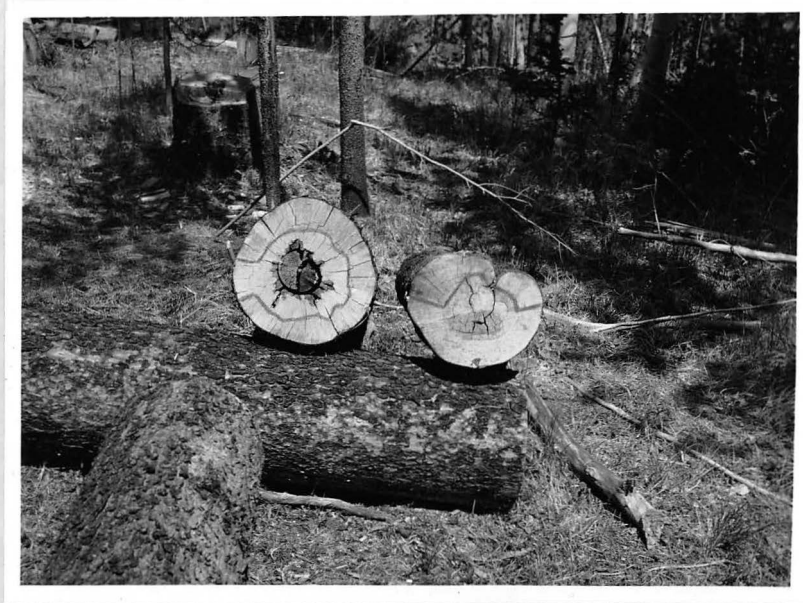

Photo 2. Butt section from two infested trees showing area with blue stain.

Photo 3 Pine to left has nearly 90 percent of the infested bark removed by woodpeckers. Pines to right are not infested by beetle brood.

Photo 4. Showing manner in which treated trees were examined. Light areas indicate where the bark has been removed for brood examination. Camera case indicates end of infestation. Note hacking at base of stump in foreground.

Photo 5. A strip of bark showing larvae killed by the ortho-oil treatment.

Photo 6. This tree illustrates good burning at base. Note how wood has been charred in places where the bark has been burned off.

Photo 7. The two trees to the left have been properly burned. Note lack of foliage where fire has crowned out. Trees to right not treated.

Photo 8. Part of trunk showing poor burning. Area just left of stump is end of effective burn. Note book indicates height of infestation.